

USE OF ULTRASONIC WAVES IN MEDICINE

by

INTESAR HUSAIN ZAIDI

B.Sc.A.H., Punjab University
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Major Professor

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INTRODUCTION

Ultrasonic waves, the inaudible waves of sound, have been used in medicine for about a quarter of a century. Their unique properties have been applied in industry, signaling and many other fields before their use in medicine. In recent years, these waves have become increasingly important. Research is being performed which seeks to adapt them in the various branches of medicine and surgery. These waves are now being utilized both for diagnostic and therapeutic purposes.

Diagnostic ultrasonography has certain advantages, in some cases, over other methods of diagnosis. It can produce a cross sectional picture of part of the body examined without the superimposition of structures and, therefore, is valuable in certain branches of medicine.

Extensive research for the utilization of ultrasonic waves in obstetrics and gynecology has been performed by Donald and others (1), (2), (3), (4). New instruments and new technics for the early detection of the fetus and measurement of the fetal head before parturition are being developed.

Research is also being accomplished in the field of ophthalmology. Baum and Greenwood hold the view that no other method of diagnosis can yield the information as obtained by ultrasonographic technics in ophthalmology (5); such as measurement of the distances between various structures of the eye and size of the eyeball.

In therapeutic medicine, ultrasonic waves have been utilized in the treatment of certain diseases of the spine, joints, skin, respiratory tract and certain painful conditions involving the nervous system. As the ultrasonic therapy advances, interest in the study of the biological effects of these waves is also increasing. Therefore, effects of ultrasonic waves on

blood, tissues, proteins, liver, kidney, ovaries and other important organs of the body are being studied.

Ultrasonic waves are also being employed for the surgery of the brain. It has become possible to produce effects of the desired dimensions and location, deep in the brain, without causing damage to the intervening or the surrounding tissues. Principles and technics of the neurosurgery with ultrasonic waves are being further investigated by Fry et al.

In veterinary medicine, ultrasonic waves are utilized less frequently and their uses are confined mainly to therapeutic purposes. For diagnostic purposes these waves are seldom used in veterinary medicine.

The purpose of writing this report has been to collect information on the principles of utilization of ultrasonic waves in diagnostic medicine and their physical and physiological influences on which is based their implication in therapeutic medicine.

It is hoped that this report will prove helpful in providing a better understanding of the basis of ultrasonic waves in medicine. It may also be useful in the possible application of the principles and procedures of the ultrasonic diagnosis and therapy as used in human medicine to the conditions in which these waves have not previously been used in veterinary medicine.

Ultrasonic or supersonic waves are the sound waves of frequencies beyond the range of audibility of human beings. Their frequencies are more than 200 kilocycles per second (roughly one hundred times higher than the upper limit of human hearing). They represent a purely mechanical vibration and are quite distinct from ionizing radiation of any sort (6).

In non-viscous fluids, this wave motion is propagated as a longitudinal wave while in the viscous fluids and solids a shear or transverse wave is also propagated in the body of the material. A rayleigh or surface wave is produced at an interface (7). The property of ultrasonic waves to be converted into different types of waves in different media made their use possible in the different fields.

HISTORY

In 1880 the piezoelectric effect was discovered by the Curie brothers (8). It was found that certain crystals, such as quartz or barium titanate, develop electric charges at their ends when compressed along their axis of symmetry. Conversely, when charged electrically, they change their length. If an alternating current is applied to a slice of such a crystal, a longitudinal wave is generated by the movement of the crystal and ultrasonic waves are produced. Ultrasonic waves can also be produced by magnetostriction (106).

Langevin was one of the first to apply piezoelectric effect for the generation of ultrasonic waves (9). He was commissioned by the French Government during the First World War to find the means of locating enemy submarines which at the time were attacking the French vessels. Ultrasonic waves were considered to be the best means for this purpose because they are inaudible and can easily propagate in water. These waves were traversed in all directions. In the presence of a submarine, the waves were reflected as an echo and could

be recorded. Since then ultrasonic waves have been widely used. Successful attempts to adapt them to industrial use were not reported until 1933 (10).

The first known report concerning the conduction and absorption of ultrasonic waves in human tissue was published in Germany in 1939 (11). Very little work in this field was done in the next five years. It was during the Second World War that radar and sonar technics were developed. Principles of these instruments supplied the basic information which led to the development of modern ultrasonic diagnostic technics in medicine.

In 1945 Firestone utilized the supersonic reflectoscope for the localization of flaws in metals (12). In 1948 Ludwig and co-workers first published data showing that the ultrasonic echoes could be received from gallstones and other structures within the human body (13). Henry also succeeded in obtaining a cross-sectional representation of the structures in the fore arm, a cancer in the breast and a gall bladder filled with calculi (14). They employed the pulse echo and horizontal scanning technics. Wild (15) and Reid (16) used similar technics and demonstrated the thickness of the bowel wall. Later, Wild and co-workers (17) examined the soft tissues of carcinoma of breast and tumours of brain. After these initial developments, work with ultrasonic waves was accelerated in many countries. In this way a new tool of biological research was developed.

METHODS OF APPLICATION

Ultrasonic waves are applied to the body through a probe or head of the instrument producing ultrasonic waves. It propagates the waves into the tissues. Intensity of ultrasonic waves is measured in watts per square centimeter.

Ultrasonic waves are rapidly absorbed in the air. Therefore, to help maintain an accurate contact between probe and the skin, it is necessary for the hair to be removed from the site of ultrasonic application. In addition to it, a contact medium is also applied on the skin in order to avoid any air space between probe and the skin, particularly on the uneven areas of the body. Contact media commonly used are mineral oil, ointments and a gelatinous substance commercially prepared for this purpose. Warming of the contact medium is considered by some workers to render the ultrasonic waves more affective (18).

Sometimes the ultrasonic waves are applied under water. This procedure is easier to carry out than is the use of contact medium and eliminates the possibility of the presence of any film of air under the probe. In the opinion of some workers this method is preferable to the contact medium method (19). It is considered most useful for areas of the body where a close contact between the skin and probe cannot be maintained, particularly when the probe has to be moved around.

Treatment through water can also be carried out with the help of a special funnel, chair (20) or a rubber container filled with water (21).

USE OF ULTRASONIC WAVES IN DIAGNOSIS

Extremely short pulses of ultrasonic waves are being utilized for diagnostic purposes in human medicine. Each pulse lasts for only a few millionths of a second. The average power levels used are approximately one-thousandth to one one-millionth as great as those used for therapeutic purposes. Such low intensities of ultrasonic waves are not reported to exert any biological influence on the body. It is, therefore, generally stated that the diagnostic value of ultrasonography depends upon the body's



Figure 1 Illustrating that echoes can be detected from tissue interfaces only if the sound beam crosses the interface at right angles as in (A). At other angles of incidence (B), the echo does not return to the probe.

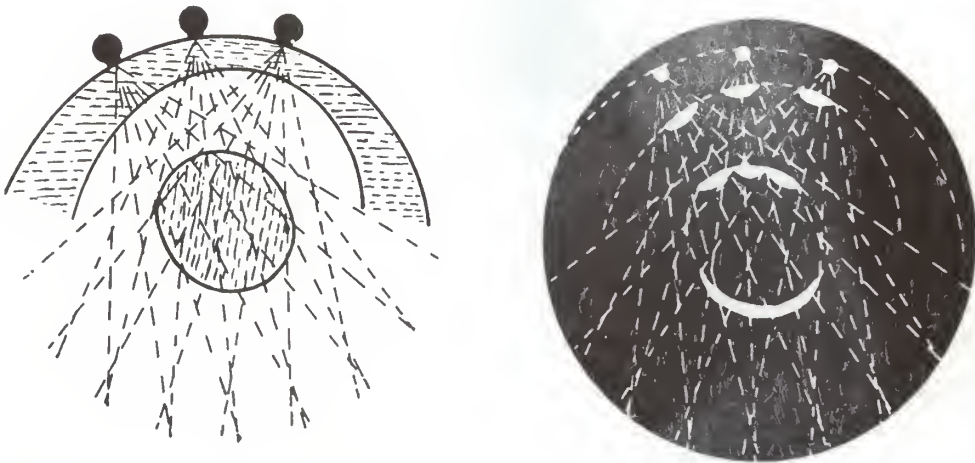


Figure 2 (Left). Three overlapping sector scans. At each position of the probe it is rocked through an angle of about $\pm 30^\circ$ from the perpendicular to the skin at that point. The broken lines each represent the path of a single pulse of sound energy. In practice a pulse is transmitted every $\frac{1}{2}^\circ$ of each individual sector scan and there are about 50 or 60 overlapping sector scans equi-spaced round the skin.

(Right). A cross-sectional display showing the left-hand figure superimposed on the echo pattern which would be recorded if sector scans were carried out only from the three positions of the probe on the skin.

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Springfield, Illinois, U.S.A

effect on ultrasound, whereas the therapeutic value depends upon the ultrasound's effect on the body (22).

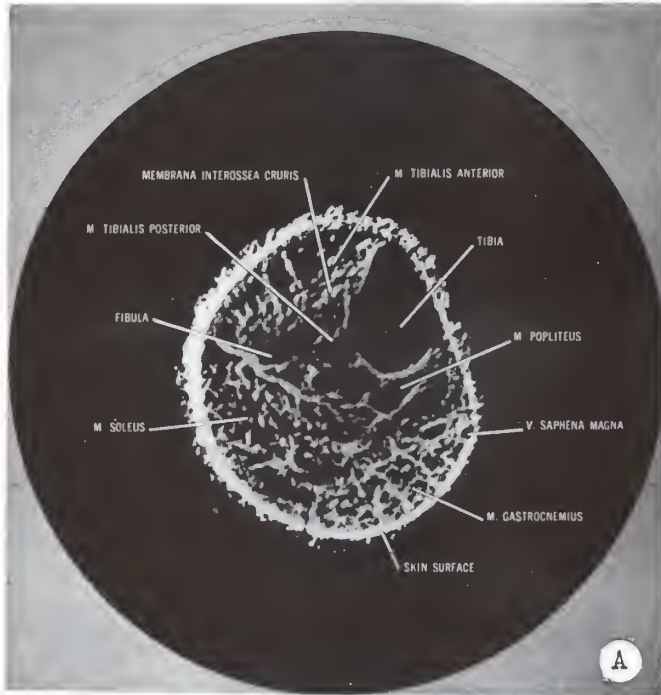
Ultrasonography is based on the principles of echo ranging, which is also utilized in radars, echo sounders and submarine detection equipment used at sea. In radar the energy used is in the form of electromagnetic waves. These waves travel much faster than sound waves and can be used for distances of hundreds of miles. In other technics sound waves are used which travel much slower than electromagnetic waves and operate on short distances of only a few centimeters.

The sound waves travel in straight lines more or less at a constant speed through the tissues. Whenever these waves impinge on a tissue interface, some of the sound is reflected as an echo. When the echo returns to the probe it can be detected. For the detection of echoes, it is necessary for the reflected waves to return to the probe. In practice, however, all the echoes do not return to the probe. When the sound waves impinge on a tissue interface, the reflected waves return along the path of the incident waves if the interface is at right angle to the direction of motion of the sound. The waves that do not obey this rule do not return to the probe and are lost (Fig. 1). To avoid the loss of reflected waves, automatic scanning devices have been developed which maintain the probe at a constant pressure and desired angle on the skin of the body.

By making certain electronic modifications, the recorded echoes can be presented as bright dots of light on an oscilloscope (Fig. 2). An oscilloscope utilizes a cathode ray tube which is the type of tube used in television sets (23). A cathode ray tube produces electrons from the electric current. The electrons are accelerated along the axis of the tube and at the same time they are focussed onto a fluorescent screen. At the point where they strike

EXPLANATION OF PLATE I

- A. Ultrasonogram of a normal human leg.
- B. Ultrasonogram of a normal human neck.



the screen a bright spot of light appears (24). The distance between the dots represents the time which elapses between the pulse being sent out and the echo returning to the probe. This gives a measure of the distances of the interfaces from the probe. The intensity of the dot represents the strength of the returning echo and gives the density of the interface (25).

After all the echoes have returned to the probe a new pulse is generated and passed adjacent to the path of the previous pulse. In this way a new line of spots adjacent to the preceding line is produced on the oscilloscope. Thousands of pulses are formed every second and passed in a slightly different direction through the object being studied.

A camera is placed in front of the oscilloscope screen and shutter of the camera is left open. While the probe is being scanned in a regular pattern from one side of the object to the other and while simultaneously the lines of dots are being produced on the screen, their images are focussed on the film. When the film is developed, the transient flashes of light are seen to have joined up to form a cross-sectional view of the part of the body examined. This picture is an ultrasonogram (Plate I).

Two types of technics are generally used for the application of ultrasonic waves for diagnostic purposes. These are A-scope, or amplitude depth technic and the B-scope, or compound scan technic with or without focused sound beam. The A-scope presents the echoes in relation to time and distance on a single line and single direction only (26). The B-scope is a compound scanning technic. It propagates the waves in many directions. It is possible with this technic to obtain more reliable pictures of the structure being studied (Fig. 3).

Diagnostic ultrasonography, in certain cases, is more useful than other diagnostic aids. It gives a cross-section view of the part examined including

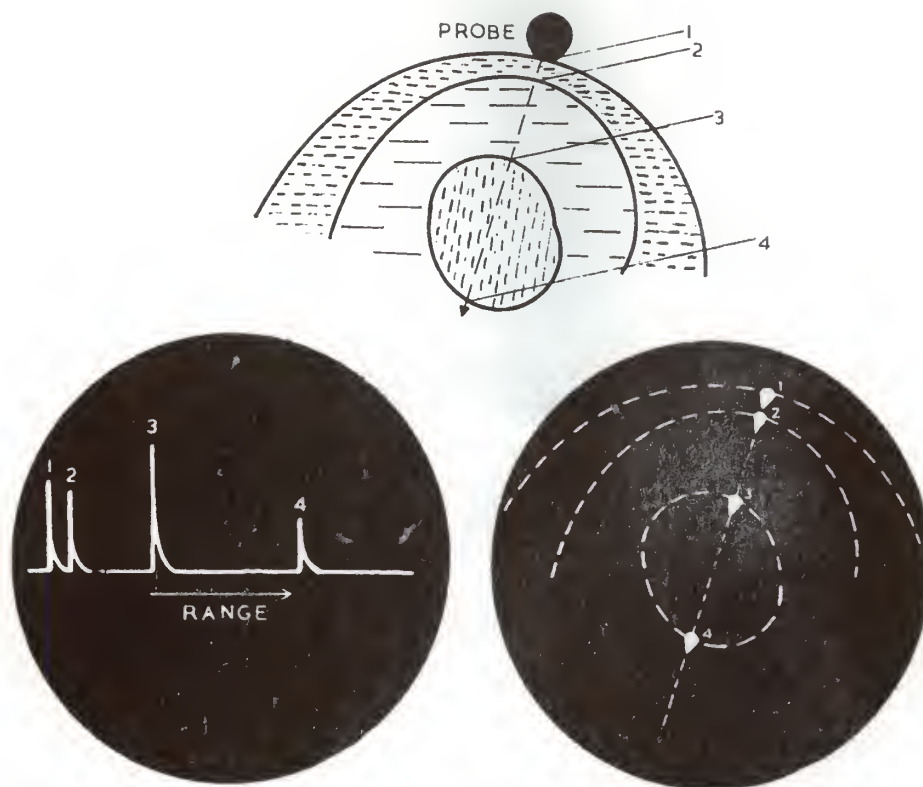


Figure 3 (Top). Diagrammatic cross-section of the abdomen of a hypothetical patient showing (broken line) the path of the sound energy originating from the probe at (1) and crossing interfaces (2), (3), and (4).

(Lower left). A-scope display showing the time-base which moves from left to right and is deflected vertically by the 'transmission break-through' (1) and echo signals from the interfaces (2), (3), and (4).

(Lower right). A 'compound' cross-sectional display showing the time-base originating from the point (1) corresponding to the probe position on the patient's skin, and moving in the direction of the sound. Signals from (2), (3) and (4) produce brightness modulation of the trace.

courtesy: Charles C. Thomas, Publisher
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the soft tissue structures which may not become easily visible by other methods. An ultrasonogram, moreover, is obtained without the superimposition of structures which is characteristic of radiographs. It may also help in the detection and determination of the position of abnormal tissues or foreign bodies which radiographic examination may not reveal.

In human medicine, the diagnostic ultrasonography is used most commonly in neurology, cardiology, obstetrics and gynecology, internal medicine and ophthalmology. These waves are also being used in some other branches of medicine but comparatively to a lesser extent.

Leksell was the first to describe what has come to be known as echo-encephlography (27). Gordon (28), Vlieger et al. (29), Taylor (30) and many others have also made important contributions to this subject. The progress with ultrasonic diagnosis has been slower in the central nervous system than elsewhere. This is because the intact skull creates a significant barrier to the transmission of sound waves. In the temporal bone, for example, the half intensity power distance at a million cycles per second is $1/2$ mm. (31). This resistance to the conductivity of the ultrasonic waves, results in the production of heat which may have a harmful effect on the brain tissues.

Ultrasonographic techniques have been found to be of value in making an accurate measurement of the midline displacement of the brain (32). This is determined by measuring the distance to the middle from both sides of the skull. This method is considered extremely valuable in the differential diagnosis of acute cerebrovascular accidents, and could readily distinguish between major arterial occlusions and space occupying hematomas, cranial abscesses and complications due to intracranial injuries (54).

Location of the cerebral ventricles by ultrasonic waves was first performed by Ballantine et al. in 1950 (33). This was performed without the

injection of air into the ventricles. Tumours of the brain have been detected by Tanaka et al. (34), (35), (36), (37), Gordon (28), Taylor et al. (30) and many other workers. A hematoma of the brain can also be detected and it is possible to differentiate it from other space occupying lesions, as reported by Taylor et al.. Location of the hematoma, whether subdural or extradural, can also be determined by this technic (29).

Ultrasonic waves have also been used for the study of the hypophysis (38), small localized lesions in white and grey matter of brain (39), intracranial lesions following injury (32) and examination of the pineal body (40). Fry and co-workers have reported a method of differentiation between pathogenic mechanisms underlying a parkinsonian tremor and rigidity as indicated by ultrasonic irradiation of the human brain (41).

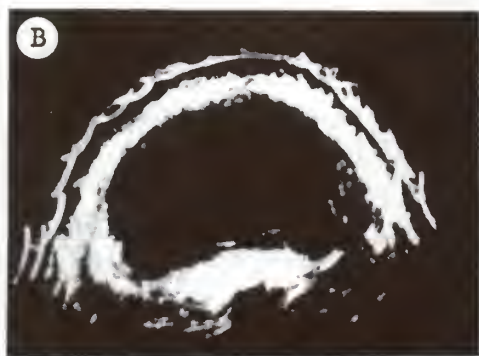
The ultrasonic waves are used in cardiology. In this branch of medicine, ultrasonographic technics have been used to produce ultrasonic cardiograms. With this technic, movement of the left ventricle wall in the normal and in the diseased heart as well as movements of the left atrial wall in mitral stenosis have been reported (42). It is also possible to make a continuous recording of the movements of the heart wall (43). It has become possible to determine volume changes in the heart by the method devised by Keidel and Arvidsson (45). Comparative studies on heart patients during the decompensation and recompensation stages of the heart have been performed by Schmitt et al. (46).

Atrioventricular valve motility and the mitral and aortic valve measurements have been recorded in living human patients (47). Structures of the heart can be studied by the intracardiac method developed by Cieszynski (48). It is also possible to diagnose abnormal structures present in the heart by

EXPLANATION OF PLATE II

- A. Photograph of transverse scan of normal human abdomen.
- B. Photograph of transverse scan of human abdomen distended by a large ovarian cyst.

PLATE II



close scrutiny of the ultrasonic cardiogram. Detection of intra-auricular tumours and thrombi has been reported by Effert and Domanič (19).

In obstetrics and gynecology, use of ultrasonic waves is becoming quite significant in certain instances. It has been found that the fetus can be detected by ultrasonic echoes. This detection is possible many weeks before the fetus can be seen by radiographic methods (2). The tissue interface can be recorded by ultrasonic waves much before the fetal skeleton can be recorded on a radiograph. Normal or abnormal presentation of the fetus can also be detected by the determination of the position of fetal head. Certain conditions of the ovaries, such as ovarian dermoid cyst and ovarian carcinomatosis have been identified by the use of ultrasonic waves (50), (Plate II). Diagnosis of hydatiform moles and fibroid tumours is also possible (3).

Measurement of the fetal head has been carried out in a number of cases. Such measurements are very useful in anticipating possible difficulties in parturition. Cephalometry with ultrasonic waves has been found quite accurate when compared with caliper measurements of the head after delivery of the fetus. An error of even 2 mm, in the opinion of the workers, can be regarded as a poor result (2).

In internal medicine, ultrasonic waves were first utilized when Ludwig et al. succeeded in detecting stones in the gallbladder and foreign bodies in tissues (51). Size, shape and structure of tumours was studied by Wild and Reid (52) and others (53), (54). This was done in intact living human bodies. Other soft tissue structures of the body could also be detected (56), (57).

Ultrasonographic technics have been used to visualize the anatomical location of edematous fluid in various parts of the body (58). Detection of

edema is based on the separation of two tissue interfaces in an ultrasonogram, which in a normal case, should be located close to each other. It is reported that an ultrasonogram will reveal a carcinoma of the breast which was not palpable prior to the surgery (59).

Foreign bodies, tumors, hematomas, abscesses and cysts can also be detected by the use of ultrasonic waves (51), (53), (57). Measurements of the dimensions of internal organs in the living animal is described by Siniakov (60).

Work has been done with the use of ultrasonic waves in ophthalmology. Baum and Greenwood hold the view that no other method can yield the information which is obtained by ultrasonographic techniques in ophthalmology (5). Distances between various structures of the eye, such as between the lens and retina, and size of the globe of the eye can be measured by ultrasonic waves (61), (62), (64). Detection of intraocular foreign bodies (63), (66), (67) tumours in the orbit (65) and hemorrhage in the vitreous chamber (68) have also been reported in the literature.

Ultrasonic waves are very useful in the diagnosis of certain other conditions of the eye. Acute dacryocystitis, for example, can be determined by the use of ultrasonic waves (69), (70). Choroidal detachment (71), rupture of the sclera (72), (73) and detachment of the retina (74) have also been diagnosed.

In dentistry, ultrasonic waves have been utilized for the examination of internal structures of teeth (75). It has been found that the absorption of ultrasonic waves increases as the vitality of teeth decreases. This principle forms the basis for a sensitive method of measuring the viability of a tooth. It makes possible the detection of caries in very early stages,

since the carious process causes alterations in the structure of the tooth and an acoustic interface is established.

Ultrasonic waves have been employed in the diagnosis of cancer. The basis of such a diagnosis is the fact that the intensity of the sound which returns from the cancerous tissues is greater than the intensity of sound that returns from equivalent surrounding normal tissues (76), (78). Ultrasonic diagnosis may be possible in the early stages of cancer (77).

In animal husbandry, the principal use of ultrasonic waves is in the determination of the thickness of muscles in bovine and swine (79), (80). These measurements are useful in the selection of meat animals that produce a high percentage of their weight in the more desirable cuts. Other methods presently used for determining farm animal physical composition are human judgement, knife probe, conductivity probe and carcass analysis. Animals which are probed with a conductivity probe or a knife are subject to infection in the incision. None of the old methods are considered to be completely satisfactory in respect to accuracy, convenience and cost. The ultrasonic method, therefore, seems to be the most desirable method. Ultrasonic method for the determination of the thickness of muscles has been reported to be reasonably accurate (81).

The entire field of ultrasonic diagnosis is based upon the preparation of good ultrasonograms and their correct interpretation. Interpretation of the ultrasonograms is the most critical aspect. It requires the knowledge of normal structures and ultrasonograms of the part of the body examined.

USE OF ULTRASONIC WAVES IN THERAPY

It is reported that sound waves were used for therapeutic purposes in the middle ages. A big musical organ was provided with a glass sound board.

Patients placed on this sound board were subjected to vibrations. This treatment was performed mainly on mental patients (82).

In therapy, relatively high levels of ultrasonic energy are used which produce mechanical and physiological effects. The therapeutic value of ultrasonic waves, therefore, depends upon the effects of these waves on the body.

The intensity of ultrasonic energy used in therapy ranges from 1 to 3 watts per cm^2 . At one megacycles per second the molecules of the medium execute small oscillations about their mean positions with an amplitude of about 2×10^{-6} cm, or 0.02 microns. The greatest velocity of the particles is about 10 cm per second and the maximum acceleration during their to and fro movement is 7×10^7 cm per second per second. Therefore, although the linear movement and velocity of the individual particle is low, the acceleration is very rapid. This may give rise to local disruptive forces, not great enough to break up molecules and produce chemical changes, but great enough to produce mechanical changes. These mechanical changes, may alter the biological membranes which then result in an increase in the permeability of the membranes to fluids. Mechanical changes also cause a rise in the temperature of the tissues (83).

The thermal effect of ultrasonic waves is generally considered to be the main therapeutic effect of ultrasonic treatment. However, some investigators are of the opinion that besides the thermal influence, an unknown action exists which aids in the recovery of the patient to an extent more than could be accounted for the thermal effect alone.

Another effect of ultrasonic therapy is fluid absorption. When the doses are adequate, fluid is increased in the interstitial tissues. It is supposed that the gels are changed to sols due to absorption of fluids.

During therapy, ultrasonic waves can be applied to the patient by various methods. These methods are aimed at achieving the greatest benefit by influencing, in the most suitable way, the part of the body to be treated.

In local treatment, ultrasonic waves are applied directly on the affected area. Treatment of the cutaneous lesions with induration, such as keloid, is an example of local treatment.

Ultrasonic waves may be applied to the nerve plexus along peripheral nerve trunks. This is thought to influence the organs at the nerve endings.

Ultrasonic application to the autonomic nervous system produces a sedative action on the nerves. The sound waves in this method of treatment have a specific effect on the nervous system because the nerve plexuses are selectively heated with respect to surrounding tissues (84).

In combined therapy the use of ultrasonic waves is accompanied by some other form of treatment. The ultrasonic therapy may be combined with physical massage, x-rays, warm water bath, electric stimulation or a cooling shower at the site of irradiation. The combined method is employed to enhance the healing effect of the treatment.

Doppelschall or Doppler effect has also been applied in the ultrasonic treatment. The treatment is given by two persons each with an apparatus. One application is on the central area of the back with lower intensity and the other, on the peripheral area with relatively higher intensity of the waves. This method has been used for cases of ankylosing spondylitis which do not respond to other forms of treatment (85).

Indications for ultrasonic treatment are numerous. It has been utilized for diseases for which no efficient treatment was previously known. It has also been tried as an aid to other methods of treatments. As a result, the

list of diseases that can be treated with ultrasonic waves has considerably increased. The following diseases have successfully been treated with ultrasonic waves.

In human medicine, the diseases of the vertebral column that are generally treated with ultrasonic waves are spondylitis, degeneration of intervertebral disc, kyphosis, scoliosis and kyphoscoliosis.

According to Van Went, who treated about forty cases of intervertebral disc syndrome in human beings, protrusion of the nucleus pulposus in cases of disc syndrome may be caused by rupture of the annulus fibrosus due to trauma of the vertebral column. Rupture of the annulus fibrosus occur when it becomes degenerated and tension on the nucleus pulposus is increased during movement or exercise.

Nutrition of the disc comes partly from the spongiosa of the vertebral bodies by osmosis through the cartilage. A normal vertebral body is, therefore, necessary for normal metabolism of the disc. Diseases of the spine are generally associated with calcium deficiency of the skeleton, which may be detected in a radiograph. This should be considered as an abnormality of the metabolism of the bony substance leading to a deranged metabolism and degeneration of the intervertebral disc. Calcium deficiency of vertebrae may be partly due to delayed protein metabolism because the old protein is not capable of taking up calcium. The favourable action of ultrasonic therapy in such cases is probably due to the stimulation of metabolism including protein metabolism, and thus increases the calcium absorption (86). Simultaneous use of calcium, vitamin D and exercise increase the efficiency of treatment.

Doses of 1.5-2 watts/cm² have been used for the treatment of intervertebral disc syndrome in human patients. This treatment was given for a

duration of 5 minutes and was repeated twice a week. This was accomplished with a moving head vertebally and paravertebally. The waves were applied to two vertebrae above and two vertebrae below the disc that was involved. An increase in pain and aggravation of the condition temporarily followed in some of the cases following each session of treatment (87). Pain was not observed following the doses of 0.5 watts/cm^2 (88). Damage to the intervertebral disc may also cause detachment of the periosteum along the margins of the vertebral body. This detachment may lead to irritation and subsequent bone formation on the vertebral bodies (82).

Satisfactory results have been reported with the use of ultrasonic waves in treating diseases of the spine (89), (90), (91). Whether the waves were applied with a stationary or a moving head is important in treating these diseases. Application with a moving head gives better results than with a stationary head. The stage of the disease at which the treatment was begun is also very important. Most of the practitioners feel that no favorable effect may be expected if ankylosis has already developed (90), (89). With the use of a stationary head, severe pains have been reported to occur on the non-treated side. This phenomenon was observed by Zinn and Sonnenschein and was termed as ' Schaukelphenomen ' or swing phenomenon (92). This phenomenon has not, however, been reported by other workers and does not occur when the head is moving.

In addition to Van Wert's explanation of calcium absorption following ultrasonic treatment, other views concerning the beneficial effect of ultrasonic waves on vertebral diseases have been suggested. Some workers attribute the healing process in these diseases to the absorption of fluids by the tissues and to the thermal influence of the waves on the tissues (93), (94). If the fluid content of the annulus fibrosus becomes lower than normal due to

deranged metabolism, it will not be able to stand increased tension in the disc and the annulus fibrosus may be ruptured. Absorption of fluids from the surrounding tissue may bring the fluid content of the annulus fibrosus to normal and improve its function. The possibility of cavitation or some other specific action of ultrasonic waves has been proposed (95). The results of experiments performed by Mazoue et al. indicate that under experimental conditions, ultrasonic waves act on the chronaxy of the nervous system by a mechanism different from that of thermal effect or cavitation (96). Whatever the underlying mechanism of healing may be, ultrasonic waves have a beneficial effect on the vertebrae as well as on the surrounding tissues. The vertebrae are strengthened by calcium absorption and the supporting tissues softened, so that the function of the spine improves.

Diseases of the joints in which ultrasonic waves are useful are arthrosis, peri-arthritis humeroscapularis (Duplay's disease), epicondylitis, tenosynovitis and arthritis. According to Pohlman the clinical effect of ultrasonic therapy on diseases of joints is marked (97), (98). He regards it as the treatment of choice in arthrosis of the hip joint. In arthrosis deformans, ultrasonic therapy is considered to be superior to x-ray therapy (99). In Duplay's disease, disappearance of pain, increase in mobility and reabsorption of calcium have been reported after ultrasonic treatment (100).

Rheumatic joints have been treated with a combination of ultrasonic waves and cortisone. The cortisone is dissolved in glycerol and used as a contact medium. This treatment is based on the phenomenon of phonophoresis.

Cases of bronchial asthma have been treated with ultrasonic waves. In the mild cases of this disease, 70 to 80 per cent recoveries have been reported by Anstett (101). In more severe cases the recoveries were 60 to 70

per cent. The waves, in this treatment, were applied over the stellate ganglion.

Ultrasonic treatment of asthma is sometimes combined with very small doses of x-irradiation. With this type of treatment, forty-three out of forty-five cases have been reported to remain symptom free for five years (102). Intensities of 4-8 watts/cm², from a stationary head were applied for 10-12 minutes daily during this treatment.

It is believed that air in the lungs impedes the penetration of ultrasonic waves during the treatment of diseases of the chest. The rigid thorax is observed to become placid after ultrasonic treatment. The vital capacity of the lungs is increased following ultrasonic treatment and the respiratory excursion is enlarged. The patient experiences less respiratory difficulty due to increased expectoration of mucus after the treatment. The physiological bases of ultrasonic treatment of bronchial asthma may be explained by the fact that bronchi of asthmatics contain a tough mucus which is expectorated with difficulty. Ultrasonic waves are known to increase the fluid absorption. The fluid is taken from the surrounding tissues. When these waves are applied to the mucus, it also absorbs fluid and becomes soft and flabby. Therefore, expectoration becomes easier (103).

Pulmonary tuberculosis has been reported to show an improvement following ultrasonic treatment (104). The value of this treatment, however, depends upon the stage or type of lesion present in the lungs. If an active infection is not present, ultrasonic therapy may help in a favorable way by breaking of the nodule. If, on the other hand, the lesion is infective, ultrasonic irradiation may cause dispersion of the infection in the surrounding areas of the lungs (105). In the opinion of Van Went, ultrasonic treatment in

tuberculous pulmonary lesions should be disfavored both in active and inactive conditions of disease (82).

There is a great divergence of opinion in regards to the usefulness of ultrasonic waves in cardiac diseases. Some authors regard the use of ultrasound in these diseases as an absolute contraindication. Others hold the view that there is a favorable influence from ultrasonic waves on certain cardiac diseases. A case of cardiac infarction has been reported by Denier which was treated with high doses of ultrasonic waves over the stellate ganglion and preaortic plexus. The pain decreased and the feeling of oppression disappeared (107). Certain vascular conditions such as angiospasm, arteritis obliterans (108), (109) and Raynaud's disease (110) have been reported to show improvement following ultrasonic treatment. Great caution, however, is necessary during this type of treatment. Weak vessels may rupture due to vibrations of vessel walls and thrombi may become loose and form emboli following ultrasonic treatment.

Ultrasonic treatment has been applied in some cases of gastric and duodenal ulcers (111). Such treatment has little effect on fresh ulcers. However, in indolent ulcers satisfactory results have been reported following ultrasonic treatment. Perforation at the site of an ulcer is possible as a result of vibrations produced by the waves.

Intestinal peristalsis has been shown to increase after ultrasonic treatment in children and babies (112). Movement of the head of the apparatus is necessary to produce this effect. Ultrasonic waves have also been used in cases of pylorospasm. Phlorospasm has been reported to disappear after a few sessions of treatment (113).

Meniere's disease, a progressive deafness due, most probably, to an excessive amount of endolymph in the semicircular canals of the ear, has been

treated with ultrasonic waves. A special type of instrument has been devised for the treatment of this disease. The technic has been developed by James (114). The treatment is performed under local anesthesia. The waves are applied directly to the fluids of the labyrinth with a special probe in the intensities of 10 to 22 watts/cm² (31).

Tinnitus and catarrh have also responded favorably to ultrasonic therapy (115).

Various cutaneous conditions have been treated with ultrasonic waves. Dupuytren's contracture, caused by the contraction of the palmar fascia leading to permanent flexion of one or more fingers, has been reported to respond to ultrasonic therapy. Satisfactory results were obtained when the finger was treated before complete contraction had occurred. After contraction, ultrasonic treatment may be combined with x-ray therapy to obtain better results (116). A rubber bag filled with water has been used during the application of ultrasonic waves to the hand. The waves were then applied with a moving head. In the opinion of Tschannen and Sonnenschein, a decrease in the tonus of the palmaris longus muscle accounts for the improvement in the cases of Dupuytren's contracture (117).

Several unsuccessful attempts have been made to treat keloids with ultrasonic waves. However, it has been reported that a case of keloid in the scar of a gall bladder operation was cured with ultrasonic waves. Adhesions of the abdominal wall were also supposed to exist in this case and were believed to disappear following the treatment (118).

Cases of painful amputation stump have been reported to respond well to ultrasonic therapy (108), (109). Pain in the stump disappeared as a result of the sedative action of ultrasonic waves.

A special technic for the treatment of warts has been described by Buchtala (119). A little ball of wax is placed on top of the wart. The waves are applied with the stationary head of the ultrasonic apparatus. Wax melts and forms a fountain through which the warts are irradiated with ultrasonic waves. Afterwards, an areola of vesicles develop. The wart falls off in approximately two weeks without leaving a scar.

In localized scleroderma, constant success has been reported with ultrasonic treatment (120).

Ultrasonic therapy has been useful in treating leg ulcers. Fifty to sixty per cent recoveries were reported by Krebs (121). He applied the waves directly on the ulcers as well as to the surrounding areas. He observed epithelial proliferation and clearing of the ulcers after a few sessions of treatment. Some recurrences were observed. Woerber treated twenty-four cases and found improvement from the first session without any recurrences after healing (122).

Purulent inflammatory processes such as boils, carbuncles, hydroadenitis and mastitis have been treated with ultrasonic waves. Satisfactory results in these diseases have been obtained after treatment (123), (124). The moving head should not be used in such cases because the inflammation may become dispersed by this method of treatment.

In addition to the diseases already mentioned, ultrasonic waves have been used in treating certain other conditions. A brief description of some of them is given below.

Mycosis and neuralgia have been reported to respond favorably to ultrasonic treatment (125). This can be explained by the fact that ultrasonic waves have a sedative effect on pain. All painful conditions (algias), according to Van Wert, can be treated with ultrasonic waves (82).

Ultrasonic irradiation in cases of toxic goiter have given no favorable results (126). Thyrotoxicosis, however, has been treated satisfactorily (127).

Progressive muscular atrophy is considered quite suitable for ultrasonic treatment. A case of twelve years standing of this disease was cured in thirteen sessions of ultrasonic treatment (128). Sympathetic nerves in the area of progressive muscular atrophy have also been irradiated with ultrasonic waves. With this form of treatment, Rusken has reported improvement in nine cases (129). The musculature became stronger in each case.

A case has been reported, where, after the removal of the patella, the skin over the underlying tissues was only slightly mobile and the joint movement was limited. Severe pain was felt upon movement of the knee joint. After ten sessions of ultrasonic therapy the pain disappeared, the skin moved freely and the joint movements became normal (82).

Experiments are constantly being performed to explore the diseases in which ultrasonic therapy might prove useful. Although these waves are utilized much less frequently in veterinary medicine at the present time, it is hoped that their use will become popular in certain cases in the future.

BIOLOGICAL EFFECTS OF ULTRASONIC WAVES

The use of ultrasonic waves is rapidly increasing in medicine. This necessitates the study of the effects of these waves on biological tissues. Knowledge of the biological effects of ultrasonic waves aids in the evaluation of ultrasonic therapy and gives information regarding the possible effects of these waves during diagnostic uses. It also helps in the determination of the

intensities to be applied and the areas of the body or the organs to be avoided while applying ultrasonic waves.

A study of the history of sound waves reveals that as early as 1793, the results of an explosion in Landau were reported. Ninety-two newborn infants died from the sound waves. Several other infants were believed to become cretins. In 1921 when ultrasonic waves were adapted for use in navigation, it was observed that small fish coming into the field of the ultrasonic waves were killed by the effects of the waves (32). When a small animal was placed in oil in which an oscillator producing ultrasonic waves was immersed, the animal died. It was found that blood corpuscles were destroyed by ultrasonic waves (6).

The thresholds of ultrasonic energy are very important in relation to its biological effects. A particular type of tissues may not be affected at low intensities, but if the intensity is increased, the same tissues may show some biological effect.

There are physical factors which accompany the ultrasonic waves. These factors are responsible for the manifestation of the biological influences brought about by the ultrasonic waves on the tissues. The ultrasonic energy is absorbed in the tissues. This absorption causes the conversion of sound energy into heat energy. An increase in the temperature of the tissues is one of the principal factors in the manifestation of biological effects of ultrasonic waves.

Periodic pressure changes and radiation pressure from ultrasonic waves are also important factors in producing biological effects. There is a pressure of about two atmospheres between two points half a wavelength (0.75 mm) apart in the tissues. If the intensity of ultrasonic energy is increased to about 10 watts/cm², the pressure in the tissues increases

greatly and microscopic cavities are formed in the tissues (130). The cavitation may cause severe damage to the tissues. The cells are broken up and chemical changes occur. In clinical practice, however, the doses used are insufficient to produce cavitation.

✓ The phenomenon of streaming has recently been described by Hughes and Nyberg. This explains the possible mechanism of the disruption in the bacterial or cellular membranes and some other biological effects following ultrasonic application of the intensities insufficient to produce cavitation. When ultrasonic waves are applied to the tissue or a suspension of the micro-organism, the alternation of pressure between two consecutive waves of sound may cause the formation of microscopic bubbles containing gas or vapours. It has been shown that a bubble of a few microns in radius expands thousands times of its original size and then bursts into a large number of smaller bubbles in the form of a stream. These changes result in the production of a rise in the internal temperature and pressure sufficient enough to break the cell. Chemical changes such as the formation of free radicals, alteration of pH and oxidation also occur. Large polymers, such as deoxyribonucleic acid, may be broken down by the liquid shear or disruptive forces or by free radicle attack. Shearing in the absence of free radicals is thought to reduce the size of large molecules (131).

When ultrasonic waves are applied to a piece of fresh tissue, permeability of the cell membranes is increased and the interstitial substance absorbs fluids which are brought in contact with the tissue (132). Wood and Loomis first studied the mechanical, thermal, and biological effects of ultrasonic waves in the United States in 1927 (134), (135).

Effects of ultrasonic waves have been studied on bacteria. The bacilli were irradiated with 7 watts/cm². This produced injury to such a degree that

they were unable to multiply further. These bacilli were no longer pathogenic to guinea pigs, monkeys and man (136). Sterilization by means of ultrasonic waves were also tried. This method of sterilization killed 80 to 90 per cent of the bacteria. Complete sterilization, however, was not possible with ultrasonic waves (137), (138). When a bacterial suspension was irradiated with ultrasonic waves, the suspension retained its antigenicity (139).

Ultrasonic waves cause hemolyses of red blood cells (140). This effect of the waves is ascribed mainly to the mechanical influence of the ultrasonic waves. Some workers have investigated the effect of various methods of the application of ultrasonic waves on red blood cells. Effects of pulsed and continuous application were studied. In the opinion of these workers, the period between the impulses is not significant, although it has some influence on the development of heat. The intensity of the waves, rather than the duration of the application of the waves, is more important in this respect (141). Hemolysis has not been observed with the therapeutic doses in vivo. Ultrasonic waves apparently attack the membranes of the erythrocytes. The cells which escape hemolysis are observed to have tiny holes in their membranes (142).

Secondary anemia after ultrasonic therapy has not been observed. However, an increase in the eosinophils of the peripheral blood may be seen. Koepfen irradiated the bone marrow with a dose of 35 watts per cm^2 for 30 minutes. He observed an increase in the blood content of bone marrow. The bone marrow also showed an increase in eosinophils (143).

✓ In a study by Spetch et al. certain changes in the blood were noticed immediately after the irradiation with ultrasonic waves. The hemoglobin percentage was increased while number of leukocytes and erythrocytes remained unchanged. A fairly large number of immature cells were found

directly after the irradiation. The estimated sedimentation rate also increased. The differential examination showed an increase in the percentage of polynuclear cells and a decrease in the percentage of lymphocytes immediately after the ultrasonic irradiation. Following this, the reverse occurred, and this condition persisted for ten hours after the irradiation (144).

In another study where ultrasonic waves were applied for prolonged periods a decrease in the percentage of leukocytes was observed. The number of erythrocytes, however, remained unchanged. The decrease in the number of leukocytes, in the opinion of the author, was due to total degeneration and vacuolation as well as a change in the staining properties of the cytoplasm and neutrophil granules (145).

Living and dead membranes undergo changes after ultrasonic therapy. With an intensity of 1-3 watts/cm², there was a rise in the temperature of the membranes. Swelling of the membranes has also been observed which leads to increased permeability of the membranes (146).

Ultrasonic application to the tissues is found to produce changes which lead to subsequent damage to the tissues. Simultaneously, signs of regeneration of tissues are also evident. Connective tissue shows a marked proliferation as a reaction to ultrasonic irradiation (147).

Effect on the callus formation during the healing process of healthy bones has also been studied. High intensities of ultrasonic waves were used in this study. High intensities caused damage and even disappearance of the bony tissue. The damage in this case was attributed to the disturbance of circulation caused by irradiation. Therapeutic doses, however, are believed to be harmless in this respect (148).

Effects of ultrasonic energy on nervous tissue have been reported. Results provided the basis for the development of neurosonic surgery.

Different intensities and durations of the application of ultrasonic waves have different effects on the spinal cord. Irradiation at the rate of 35 watts/cm² for 4.3 seconds caused paralysis of the dependent parts. This paralysis was complete and permanent. Exposure for a shorter period of time either caused no paralysis or a temporary partial paralysis which disappeared after some time. Histological changes were produced after the irradiation. Marked abnormalities were observed in the large motor neurons of the ventral horn of the gray matter. There was a complete destruction of all nerve cells and many glia cells. Serious loss of the supporting elements occurred. The cord lost its normal texture and became very soft (149). The cell outlines were ragged and the stain was intense as compared to the staining qualities of the normal neurons. Irradiation leading to temporary paralysis produced slight changes. Low intensities or short durations produced no histological changes.

When ultrasonic waves were applied to the brain or spinal cord, a rise in the temperature of these structures was observed. The rise in temperature was not responsible for the production of changes and effects on the nervous system (150).

It was found by Bejdl that adverse effects were produced in the liver by ultrasonic energy (151). Intensities of 4 watts/cm² for 40 minutes were found to affect the liver. As early as five minutes after irradiation, the liver cells lost their capacity to store glycogen. The cells were completely destroyed after forty minutes of irradiation. Kupffer cells also showed destruction. Active hyperemia has been observed in the liver after an ultrasonic irradiation of five minutes with ten watts/cm² (152).

Kidneys, when exposed to ultrasonic waves, showed varying effects following different doses of the waves. Use of the dosage of 5-6 watts/cm²

resulted in complete destruction of some kidney cells. The changes were produced throughout the cell. The nucleus, however, was found to be more sensitive than the cytoplasm (153).

In the ovaries, increased atresia of the follicles were observed after ultrasonic application of 3-4 watts/cm². Ovogenesis and the sexual cycle were unaffected. Higher intensities resulted in atrophy of the genital tract and absolute sterility (154). Effects of small doses caused an increase of follicular growth and an early estrous cycle.

Testicles, when irradiated with high intensities of ultrasonic waves, showed damage at various sites. The cells were affected in the order of their degree of maturation. Spermatozoa during the process of division were not very sensitive to the trauma from ultrasonic waves (155).

Effects of ultrasonic waves on the heart vary according to the changes in the intensities of the waves. Hearts of cold blooded animals were shown to have a decrease in the amplitude of the heart beat after ultrasonic irradiation. In cold blooded animals it was impossible to produce the same changes by means of the alterations in the temperatures. When waves of low intensities were applied to mice or rabbits, they became more active. With higher intensities, however, they became paralysed or died (156).

Irradiation of the heart with low intensities of ultrasonic waves caused a change in the electrocardiogram. The highest sensitivity to ultrasonic waves was manifested by the bundle of His. When the bundle of His was irradiated, cardiac arrest occurred (157). Doses of ultrasonic waves which are used in diagnostic ultrasonography, however, produce no observable effect on the heart.

NEUROSONIC SURGERY

Neurosonic surgery refers to operative procedure on the brain and spinal cord performed by the application of focused ultrasonic waves with intensities sufficient to cause destruction of nerve cells.

Brain surgery has been performed either by directly cutting the tissues in the brain or by causing coagulation of the tissues by means of electrically excited probes (159). Both of these methods, inspite of extreme care on the part of surgeons, involve the danger of death or paralysis due to damage to surrounding tissues.

Ten years ago the effects of ultrasonic waves were being studied at the Bioacoustic Laboratory at the University of Illinois. Frogs were used in this study. High intensity sound waves were applied on the region of back over the portion of the spinal cord which controls the muscles of the hind leg. The sound waves were transmitted through water. It was found that after a brief exposure the legs became permanently paralysed. It was also observed that paralysis did not occur below a certain level of the intensity of ultrasonic waves even when the waves were applied for a relatively long period (163), (149), (158).

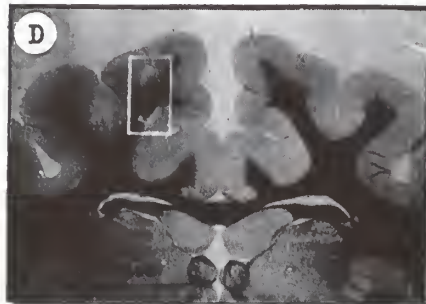
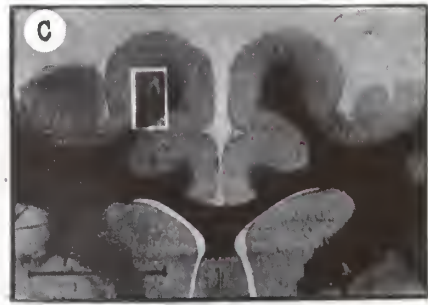
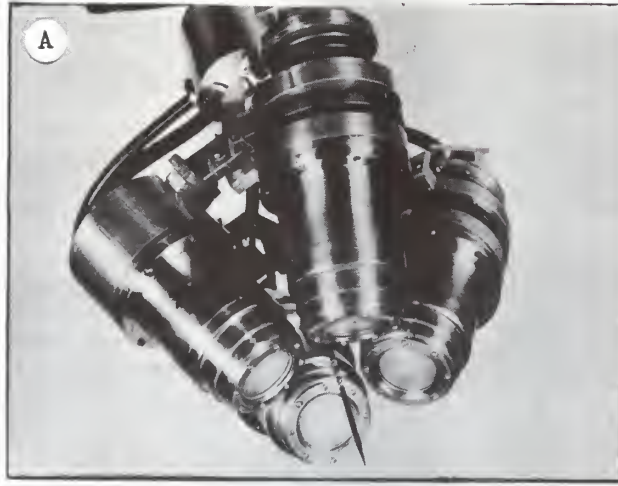
Later the experiments were performed on brain of cats and monkeys. Focused waves were applied on selected regions of the brain and it was noted that areas of a few millimeters in length could be affected without destroying the neighboring tissues (160). By this method, a new field in neurosurgery was opened.

Different types of nervous tissues have wide differences in their susceptibilities to ultrasonic waves. Therefore it is possible to destroy one type of nervous tissue by adjusting the intensity of the waves without

EXPLANATION OF PLATE III

- A. Four beam focusing ultrasonic irradiator used in neurosonic surgery.
- B. A 'light' lesion in the subcortical white matter of the brain of a cat produced in response to a suitably chosen dose of ultrasonic waves.
- C. A 'medium' lesion in the subcortical white matter of the brain of a cat produced in response to a suitably chosen dose of ultrasonic waves.
- D. A 'heavy' lesion in the subcortical white matter of the brain of a cat produced in response to a suitably chosen dose of ultrasonic waves.

PLATE III



destroying surrounding tissues. This fact is a great advantage to the neurosonic surgery. In cutting or coagulation methods some tissues in the intervening area have to be destroyed to reach the desired location for surgery. No differentiation can be made between nerve cells, nerve fibers and blood vessels. Moreover, it is difficult to produce a lesion of a definite shape and size by the previous two methods. When ultrasonic waves were used, blood vessels in the area remained unaffected and nerve tracts were not damaged. White matter of the brain has been found to be more susceptible to ultrasonic destruction than the grey matter. It is therefore possible to destroy the nerve fiber tracts surrounded by regions of the nerve cell bodies without damaging the tissues of the grey matter (161).

In the beginning a sound source with a single beam of waves were used. In this way, the lesion produced were small in cross section but relatively long. A lesion that was small in all three dimensions was difficult to accomplish with a single beam. A new multibeam instrument was later developed (162). This instrument produces four beams of ultrasonic waves which converge to a point deep within the brain (see Plate III). Each beam in its way is insufficient in intensity to produce harmful effects, but when combined at the convergent point, the intensity of the waves becomes sufficient enough to cause destruction of the tissues. In this way a lesion can be produced deep in the tissues without destroying the intervening area of the brain. The most intense area of the ultrasonic field can produce lesions as small as a few millimeters.

Experiments in neurosonic surgery have revealed that it is possible to produce temporary or reversible changes in the tissue structure. This has been demonstrated both in the experimental animals and human beings (149).

Before the application of ultrasonic waves for neurosurgery, the skull cap is removed and the dura mater is exposed. The bone of the skull must be removed because bone has a high ability to absorb ultrasonic waves. This results in excessive heating which may affect the bone itself or the underlying tissues (164). The presence of bone also disturbs the shape of the beam of ultrasonic waves. The skin of the patient is attached to a special metallic hepper which forms a sort of pan, the bottom of which is formed by the exposed dura mater. This pan is filled with degased physiological saline solution which serves as the transmission medium.

Neurosonic surgery has opened a new era in the surgery of the brain. It has rendered it relatively safe and easy. Many of the disorders of the nervous system which were difficult to treat previously, have now become possible to be treated successfully. In addition to the treatment of certain diseases such as Parkinson's disease, hyperkinesias, paresthesias, dysesthesias and irradiation of brain tumours, neurosonic surgery has opened a way for additional research in neuroanatomy, neurophysiology and neuropathology.

ULTRASONIC MICROSCOPE

Increasing research with ultrasonic waves has led to the development of an ultrasonic microscope. Ultrasonic waves with very high frequencies, which also have very short wavelengths, can be reflected and turned aside in a way similar to light rays. These waves are used in the ultrasonic microscope. The ultrasonic beam passes through the object and after being reflected by lenses, forms an enlarged image on a quartz plate. This image is in the form of vibrations in the plate and produces electrical signals.

These electrical signals are further made to produce images on an oscilloscope in the form of a greatly enlarged picture of the object (165).

ULTRASONIC BLOOD FLOWMETER

Recently another ultrasonic instrument has been developed which can measure the velocity of circulating blood. This instrument is based upon the principle that the difference in frequency between the incident sound and the sound reflected from a moving target is proportional to the velocity of the target. An ultrasonic blood flowmeter measures the shift in frequency of the ultrasonic waves which is applied to the circulating blood and reflects the velocity of blood (166).

SUMMARY

Ultrasonic waves are now being utilized in medicine; both for diagnostic and therapeutic purposes.

Piezoelectric effect has been utilized for the production of ultrasonic waves. These waves travel almost in straight lines and, in the presence of an interface, are reflected as an echo. In the diagnostic ultrasonography, these echoes are recorded and projected on the fluorescent screen as dots of light. Lines of these bright dots are photographed into a picture, the ultrasonogram. An ultrasonogram can give a cross-sectional picture of the part of body examined. Diagnostic ultrasonography is being utilized in neurology, cardiology, obstetrics and gynecology, internal medicine, ophthalmology and many other branches of medicine.

Ultrasonic waves are also used in medical therapeutics. Ultrasonic therapy is associated with an increase in the temperature of the tissues, increase in the membrane permeability and tissue absorption, deep massage and soothing effect on pain. These influences of ultrasonic waves account for their utility in therapy. Various diseases of bones, skin, respiratory tract and some painful conditions can be treated with ultrasonic waves.

Ultrasonic waves are also employed for neurosurgery. Selected parts of predetermined size, shape and location in the brain can be destroyed without any hemorrhage or destruction of the surrounding tissues. Neurosonic surgery is useful in the treatment of certain diseases.

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USE OF ULTRASONIC WAVES IN MEDICINE

by

INTESAR HUSAIN ZAIDI

B.Sc.A.H., Punjab University
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Ultrasonic waves are now being employed in medicine both for diagnostic and therapeutic purposes. These waves were first utilized during the First World War, when ultrasonic instruments were developed by the French Army to detect enemy submarines. In medicine most of the research has been done in the past ten years.

Piezoelectric effect is utilized for the production of ultrasonic waves. These waves travel almost in straight lines and, in the presence of an interface, return as an echo or reflected sound wave. The property of ultrasonic waves to be reflected as an echo from an interface of an object has been utilized for the detection of flaws in metals, the location of submarines in the sea and organs in the human body.

In diagnostic medicine, the echoes from the interfaces are recorded and projected on the oscilloscope or the fluorescent screen of the instrument. The echoes, by the use of electronic devices, are made to appear on the screen as light dots of varying intensity and distance. The distance between these dots represents the time which elapses between the pulse being sent out and the echo returning to the probe. This gives a measure of the distance of the interfaces from the probe. The intensity of the dot represents the strength of the returning echo and gives the density of the interface. When lines of these dots are photographed, the picture obtained is the ultrasonogram. An ultrasonogram can give a cross sectional representation of a part of the body examined. The soft tissue structures, which are difficult to discriminate in a radiograph, are more easily identified in an ultrasonogram. An ultrasonogram, moreover, is obtained without the superimposition of structures, which is a characteristic of a radiograph.

Diagnostic ultrasonography is being utilized in neurology, for the detection of brain tumours, hematomas, intracranial injuries, and for the

examination of normal brain structures such as pituitary and pineal body. In cardiology, these waves are used for the diagnosis of aortic and mitral stenosis, movements of the atrial and ventricular valves and pathological structures, such as tumours and thrombi, present in the heart. In obstetrics, these waves are very useful in the detection of the fetus much before it can be detected by radiographic methods. Determination of the size and position of fetal head is also possible with ultrasonic waves. In ophthalmology, these waves are employed for the measurement of distances between various structures of eye such as lens and retina and in the detection of intra-ocular foreign bodies. Gallstones, foreign bodies and tumours in various parts of body can also be diagnosed with the help of ultrasonic waves.

Ultrasonic waves are also being used for the treatment of certain diseases. Ultrasonic therapy is associated with an increase in the temperature of the tissues, increase in the permeability of the membranes, agitation or deep massage and a soothing effect on pain. These influences of ultrasonic waves on the tissues account for their utility in medical therapy.

Various diseases of spine and joints such as spondylitis, degeneration of intervertebral disc, arthrosis and rheumatic arthritis can be treated with ultrasonic waves. Certain cutaneous conditions such as scleroderma, ulcers, warts, and inflammatory processes respond favorably to ultrasonic treatment.

High intensities of ultrasonic waves can destroy the nerve cells. Effect on these waves in this respect is selective. One type of cells, at a particular intensity of waves, may be destroyed while other types of cells may remain unaffected. This phenomenon has been utilized in the destruction of selected parts of the brain, such as tumours. This is also used in the production of lesions of predetermined size, shape and location in the brain. The blood vessels in the area of the lesion produced in this way remain intact. Brain

surgery with the help of ultrasonic waves is referred to as 'Neurosonic surgery'. The greatest advantage of this type of surgery is that it involves the least possibility of damages to the neighboring tissues, which may lead to hemorrhage, paralysis or death.

In recent years ultrasonic waves have continued to be an interesting subject for research. Work is being done to utilize them in various branches of human and veterinary medicine for better achievements in these fields.